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Development of Wide Band Feeds

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Abstract

Wide Band feeds are being developed at NICT, NAOJ, and some universities in Japan for VLBI2010, SKA, and MARBLE. SKA, the Square Kilometre Array, will comprise thousands of radio telescopes with square kilometer aperture size for radio astronomy. MARBLE consists of small portable VLBI stations developed at NICT and GSI in Japan. They all need wide band feeds with a greater than 1:10 frequency ratio. Thus we have been studying wide band feeds with dual linear polarization for these applications.

1. Feed of the MARBLE Antenna

MARBLE has a 1.6-m diameter dish and a dual polarization feed of a Lindgren quad-ridged horn (Figure 1). Farfield patterns of the MARBLE were measured with a quad-ridged horn at METLAB of Kyoto University in 2010. This was a near field measurement from which it was possible to calculate far field patterns and illumination on the aperture of the MARBLE. This illumination is the actual beam pattern of the quad-ridged horn. It had been previously known that the MARBLE has lower aperture efficiency than expected. Based on the 2010 measurements, it was possible to conclude that the lower efficiency in 2.3 GHz is due to the fact that the quad-ridged horn's beam size is slightly broader than the parabola dish, causing lower frequency "spillover". We expected over 50% efficiency but measured 48%, which is acceptable. However, the situation was severe at a higher frequency; the efficiency dropped down to 10% at 10 GHz. This is due to the fact that the beam width of the feed gets narrower than the dish at higher frequencies and also that the feed was displaced from the focus. This displacement was revealed by the phase pattern. But the displacement from the focus is a tiny problem. The changes of the beam size of the feed is a severe problem, which occurs because there is no way to control the quad-ridged horn's beam size.

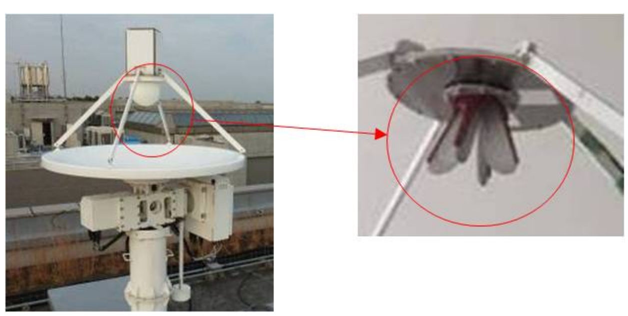
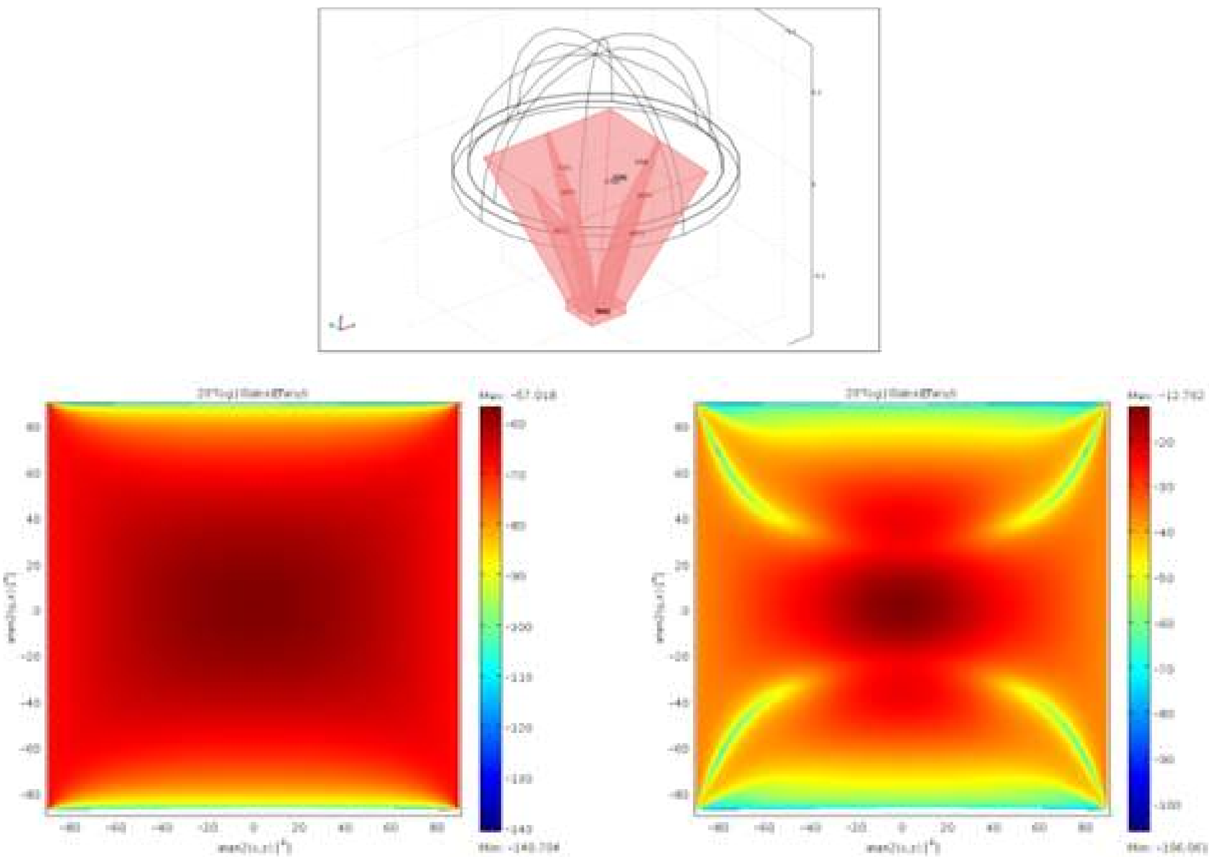


Figure 1. MARBLE and its feed.

2. Simulations of Quad-ridged Horn

A shielded quad-ridged horn was modeled with COMSOL, which was simply based on a commercial double ridged waveguide horn (SCHWARZBECK BBHA9120A) with dimensions of $W \times H \times L$ [mm] $= 285 \times 238 \times 190$. However, its aperture was modified to a square for the symmetry beam size of both linear polarizations. The calculated far field beam pattern was varied by frequency (Figure 2); however, no degree of freedom was left to shape the beam in the model. Some technique, such as resonance element or mode converter, must be developed for smart beam shaping.



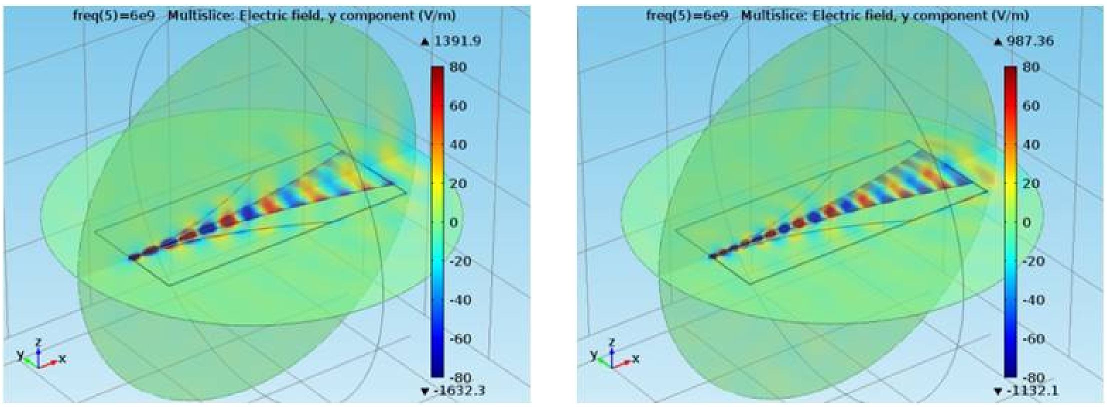
0.5 GHz 2 GHz

Figure 2. Numerical model and far field patterns of a quad-ridged feed horn.

3. Arrayed TWA

Traveling Wave Antenna (TWA) has been studied as elements of a wide band feed. The electric field is twisted along the axial in a Tapered Slot Antenna (TSA), but not in a TWA. The impedance of the TWA can be approximated with simple transmission line models, while the impedance of a TSA cannot. Thus we think an Arrayed TWA is a candidate element for the wide band feed with nearly constant beam width.

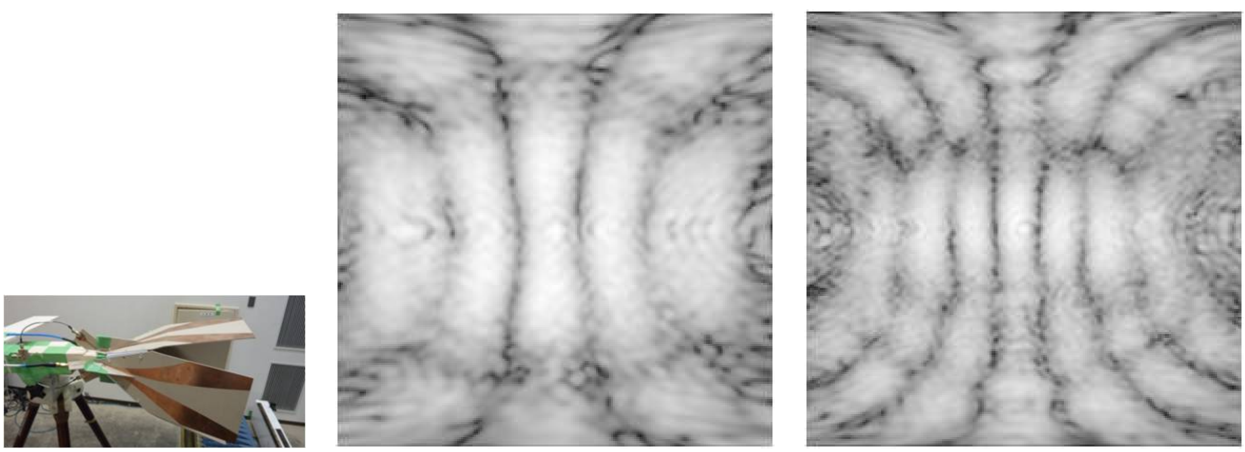
Propagation of the field around a TWA element was simulated with COMSOL under several conditions. The element size was $L \times W \times t$ [mm] $= 280 \times 120 \times 1$, and relative permittivity of the dielectric substrate was tested for $\epsilon_r = 1,\ 2.2,\ 4,$ and 10. Two examples are shown in Figure 3 for the cases of $\epsilon_r = 2.2$ and 10. Higher permittivity of the dielectric substrate enabled concentration of the field near the substrate to radiate a narrower beam as a point-like source along the plane perpendicular to the substrate. Thus selection of the dielectric substrate can be a design parameter.



$\epsilon_r = 2.2$ $\epsilon_r = 10$

Figure 3. Simulated E field component parallel to the substrate of feed element at 6 GHz.

Simple dual-polarized four-element TWA arrays were tested in METLAB. Grating lobes in far field patterns are clearly shown in Figure 4. Thus all elements are well-integrated. Feeds are made with commercial wide band dividers for convenience. Then another four small elements are added to make an eight-element TWA array to form a narrower beam shape in the high frequency end. However, power dividing did not work well and a null line was made in the beam (Figure 5). Further development should be done for the power dividing network.



4 GHz 6 GHz

Figure 4. Four-element arrayed TWA and measured beam patterns of $70° \times 70°$.

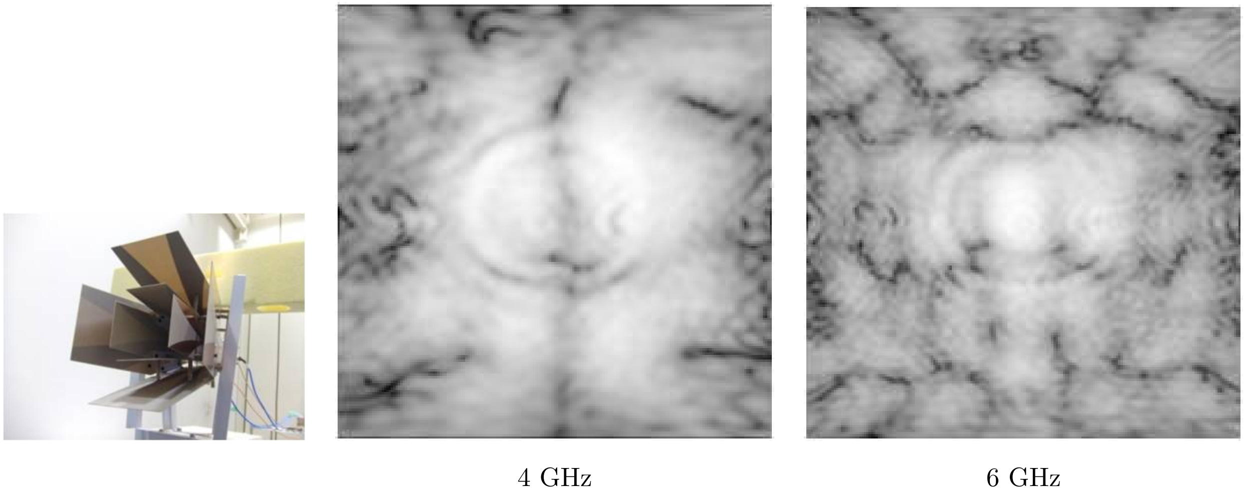


Figure 5. Eight-element arrayed TWA and measured beam patterns of $60° \times 60°$.

4. Conclusion

The arrayed TWA has been tested for development of wide band feeds. Beam patterns were studied with simulations and measurements to make an array feed; however, the power dividing network of the array should be improved to achieve a constant beam shape for the wide frequency band.